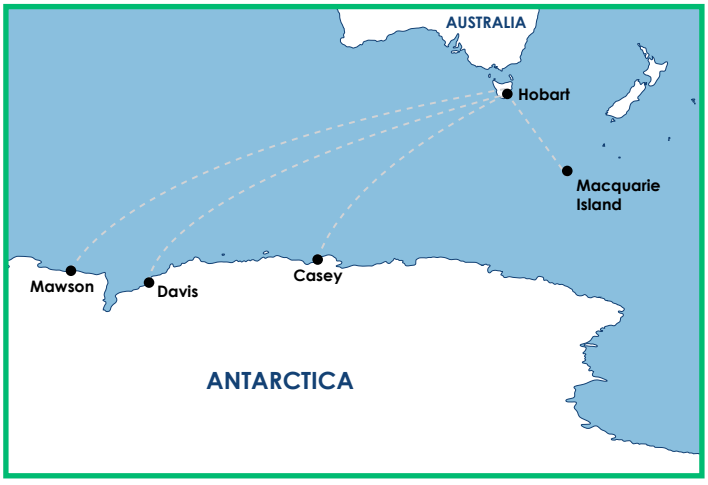
Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean

The Southern Ocean is the stormiest place on Earth, buffeted by winds and waves that circle the ice of Antarctica, sheathed in clouds that mantle a dynamic ocean with rich ecosystems. The remote and usually pristine environment, typically removed from many aerosol sources, makes the Southern Ocean unique for examining cloud-aerosol interactions and particles found in sea spray. Even though it is remote, the Southern Ocean influences the atmospheric and oceanic circulation of the entire Southern Hemisphere and beyond.

Weather and earth system models are challenged by uncertainties and biases in the simulation of Southern Ocean clouds, aerosols, and precipitation, and almost universally underestimate sunlight reflected by near-surface clouds. Many of these difficulties trace back to poor physical understanding of the underlying physical processes.

The **Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean (MARCUS)** field campaign, conducted by the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) user facility, acquired comprehensive observations over the Southern Ocean from October 2017 until April 2018. To obtain these measurements, the second ARM Mobile Facility (AMF2) was deployed on the Australian Antarctic supply vessel *Aurora Australis* as it made routine trips between Hobart, Australia, and Antarctica, and visited Macquarie Island and Australian Antarctic stations Mawson, Davis, and Casey.



The second ARM Mobile Facility traveled from Hobart, Australia, to three Antarctic research stations and Macquarie Island via the Southern Ocean. Four five-week research cruises of about 7,000 kilometers each took place over a six-month period.

The Southern Ocean's remoteness and harsh conditions make it difficult to study.

The MARCUS campaign was part of a large international multi-agency effort called the Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES). The MARCUS observations are self-standing and unique within SOCRATES. The campaign captured the variability in aerosol and cloud properties across the Southern Ocean from spring to autumn, especially in cold waters at latitudes poleward of 60°S, where supercooled and mixed-phase boundary layer clouds in the cold sector of cyclones are frequent and where past and planned observations are most sparse.

Science Objectives

MARCUS collected measurements of aerosols in the boundary layer, retrieving vertical distributions of macrophysical and microphysical properties of liquid and mixed-phase clouds, and measuring downwelling radiative fluxes over the Southern Ocean. The primary campaign objectives were to:

- understand the synoptically varying vertical structure of Southern Ocean boundary layer clouds and aerosols
- discover the sources and sinks of Southern Ocean cloud condensation nuclei and ice nucleation particles, including the role of local biogenic sources over spring, summer, and fall

- understand the mechanisms controlling supercooled liquid and mixed-phase clouds
- advance retrievals of clouds, precipitation, and aerosols over the Southern Ocean from ground-based and satellite remote sensing.

Research Instrumentation

Deployment aboard a moving vessel requires special preparation, including keeping instruments clean of sea spray and correcting for the pitch and roll of the ship. Onsite operators monitor and maintain the mobile facility to make sure the best and most complete data set is obtained.

Measurement Capabilities. They include meteorological and aerosol instrumentation, broadband and spectral radiometer suites, and remote-sensing instruments.

- Cloud Condensation Nuclei Particle Counter
- Nephelometer
- Condensation Particle Counter
- Ozone Monitor
- Surface Meteorological Instrumentation
- Cimel Sunphotometer
- Balloon-Borne Sounding System – sondes (weather balloons) launched each day at regular intervals
- Micropulse Lidar
- Microwave Radiometer (MWR) and 3-Channel MWR
- Marine W-Band ARM Cloud Radar
- Ceilometer
- Inertial Navigation System, known as SeaNav
- Sky Radiometers on Stand for Downwelling Radiation
- Laser Disdrometer
- Total Sky Imager
- Marine Atmospheric Emitted Radiance Interferometer
- Beam-Steering Radar Wind Profiler.

Data and Communications System. Continuous measurements obtained by the sensors and instruments are collected by integrated data systems. These data are checked for quality and transmitted periodically, when the ship is in port, to the ARM Data Center for storage and availability to the scientific community.

The second ARM Mobile Facility consists of instruments, operations shelters, and data and communications systems and is well-traveled on the high seas.

Using an ARM Mobile Facility. Mobile facility deployments are determined through a user proposal process. An AMF can be deployed for stand-alone campaigns or for collaboration with interagency experiments. Scientists interested in using an AMF are encouraged to submit proposals at the following web page: ***www.arm.gov/research/campaign-proposal***.

Collaborations

The ARM Facility is collaborating with the Australian Antarctic Division and the Australian Bureau of Meteorology on the MARCUS campaign.

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www.arm.gov/research/campaigns/amf2017marcus

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Additional information is available on the ARM website at www.arm.gov.